

The new Xbox 360 250GB CPU GPU SoC

Rune Jensen, Microsoft
Bob Drehmel, IBM

Hot Chips 22
8/23/2010

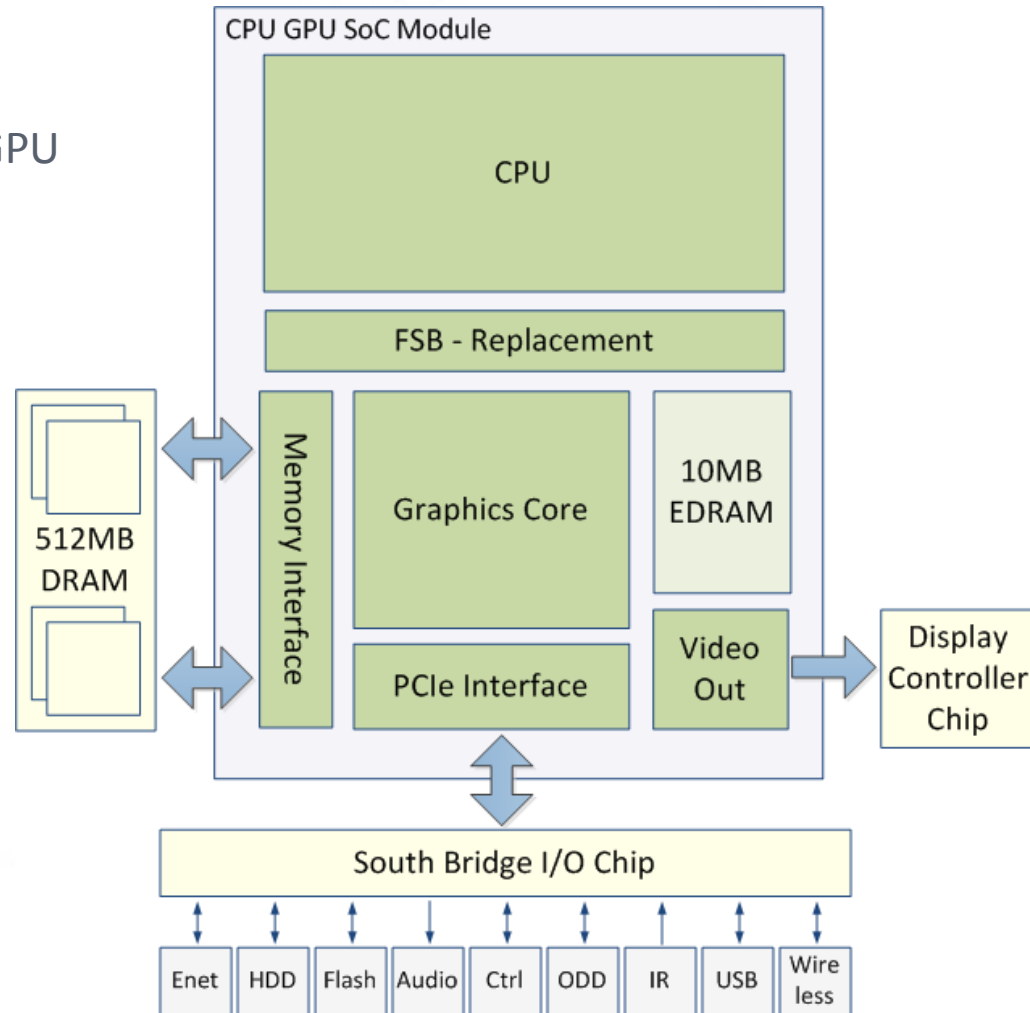


Microsoft®



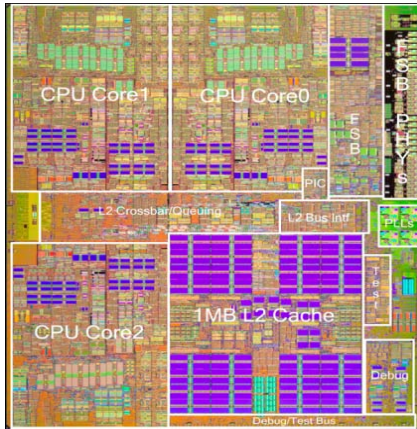
Xbox 360 250GB System

- CPU GPU SoC Module
 - CPU GPU Die
 - High Performance CPU & GPU
 - GDDR3 Memory Interface
 - Video Output
 - PCIe
 - Embedded DRAM Die
- Custom South Bridge
 - IO Connectivity
 - System Management
- Custom Video Display Controller
- Optical Disk Drive
- Flash and IO Connectivity
- 250GB HDD
- Wireless 802.11N Integration

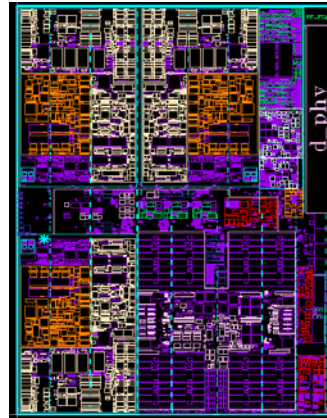


CPU, GPU Process Migrations

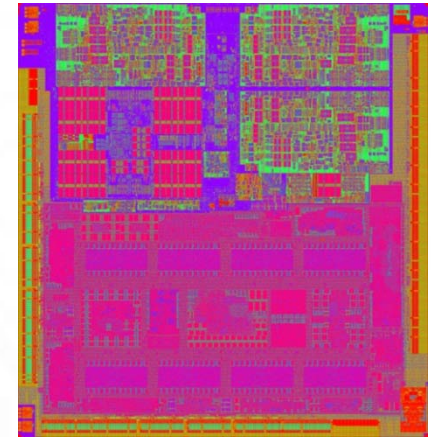
CPU



90nm, 2005

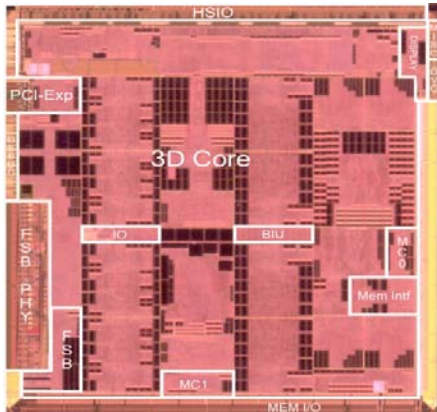


65nm, 2007

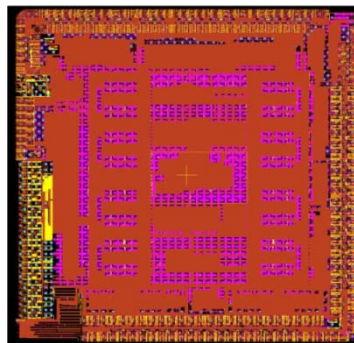


45nm, 2010

GPU



90nm, 2005



65nm, 2008

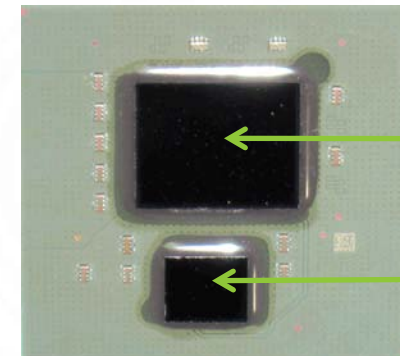


Motivation for Integrated CPU GPU SoC

- Cost and Power Savings
 - Front Side Bus Removal
 - Single Package
 - IBM 45nm SOI Technology
- Simplified Console Design
 - Motherboard Footprint
 - Power Delivery
 - Thermal Design
 - Single Heatsink + Fan



35x35mm Package,
1156 Balls



CPU GPU SoC: Features & Block Diagram

CPU

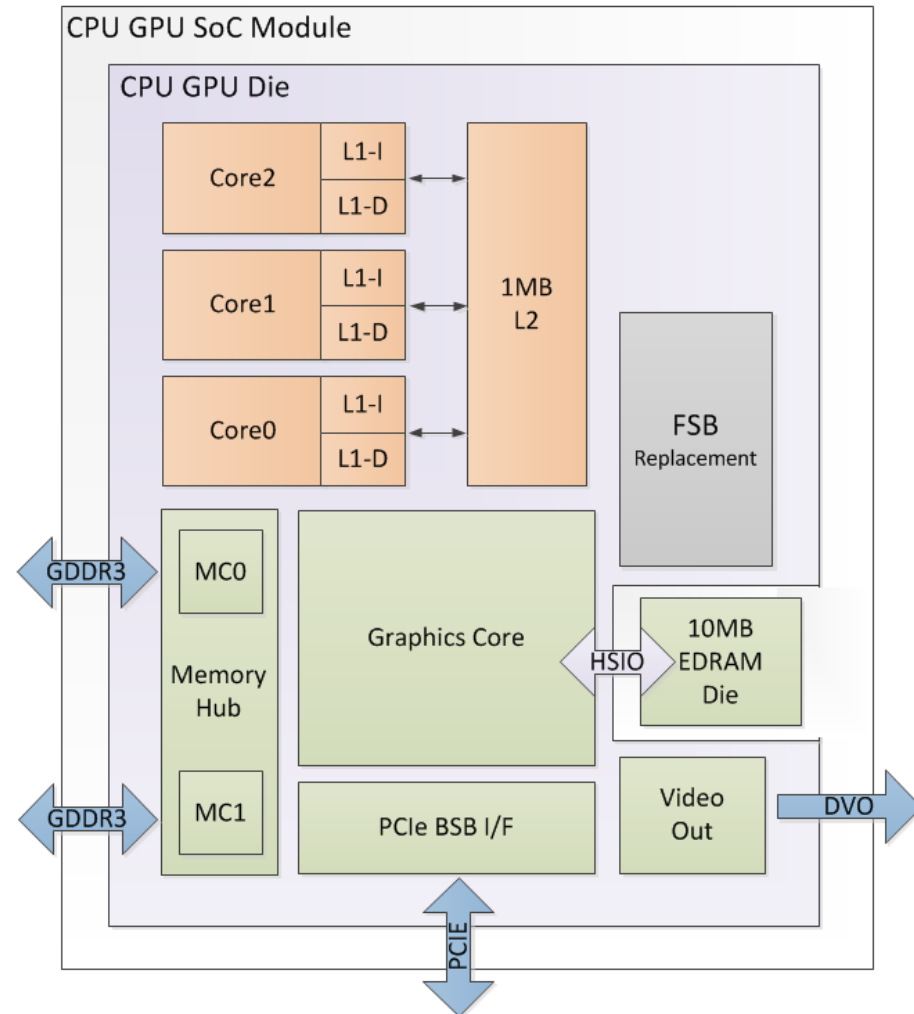
- Three 3.2 GHz PowerPC® cores
- Shared 1MB L2 cache
- Per Core:
 - Dual Thread Execution
 - 32K L1 I-cache, 32K L1 D-cache
 - 2-issue per cycle
 - Branch, Integer, Load/Store Units
 - VMX128 Units enhanced for games

GPU

- 48 parallel unified shaders
- 24 billion shader instructions per second
- 4 billion pixels/sec pixel fill rate
- 500 million triangles/sec geometry rate
- High Speed IO interface to 10 MB EDRAM

Compatibility

- Functional and Performance equivalent to prior Xbox 360 GPU/CPU
- FSB Latency and BW match prior FSB



Technology

Chip Statistics

- 372M transistors
- 45nm SOI, Ultra-low k dielectric
- 10 levels of metal
- 153 array types, ~1000 instances
- 1.8 million flip flops
- 6 PLLs
- 12 clock domains
- Compared to 2005 CPU GPU
 - >60% Power Reduction
 - >50% Silicon Area Reduction

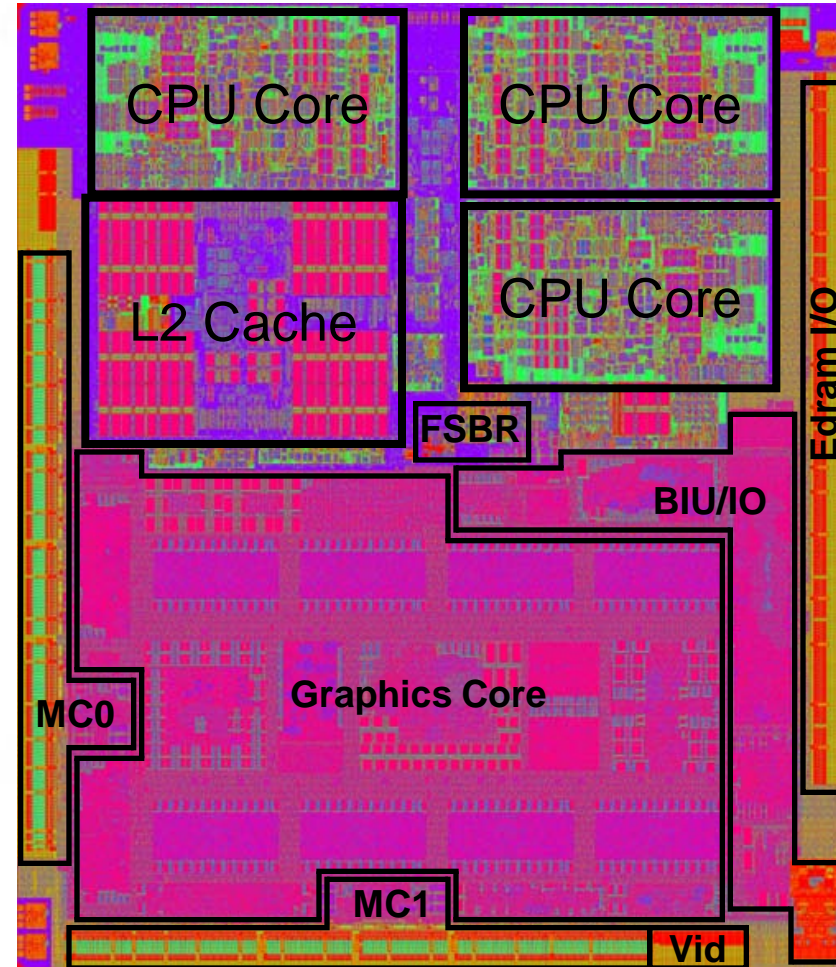
Package Technology

- 35mm FC-PBGA (3-2-3) build-up layers
- Lidded Multi-Chip Module
- High speed interface to on-module EDRAM
- C4 Pitch: 151um minimum

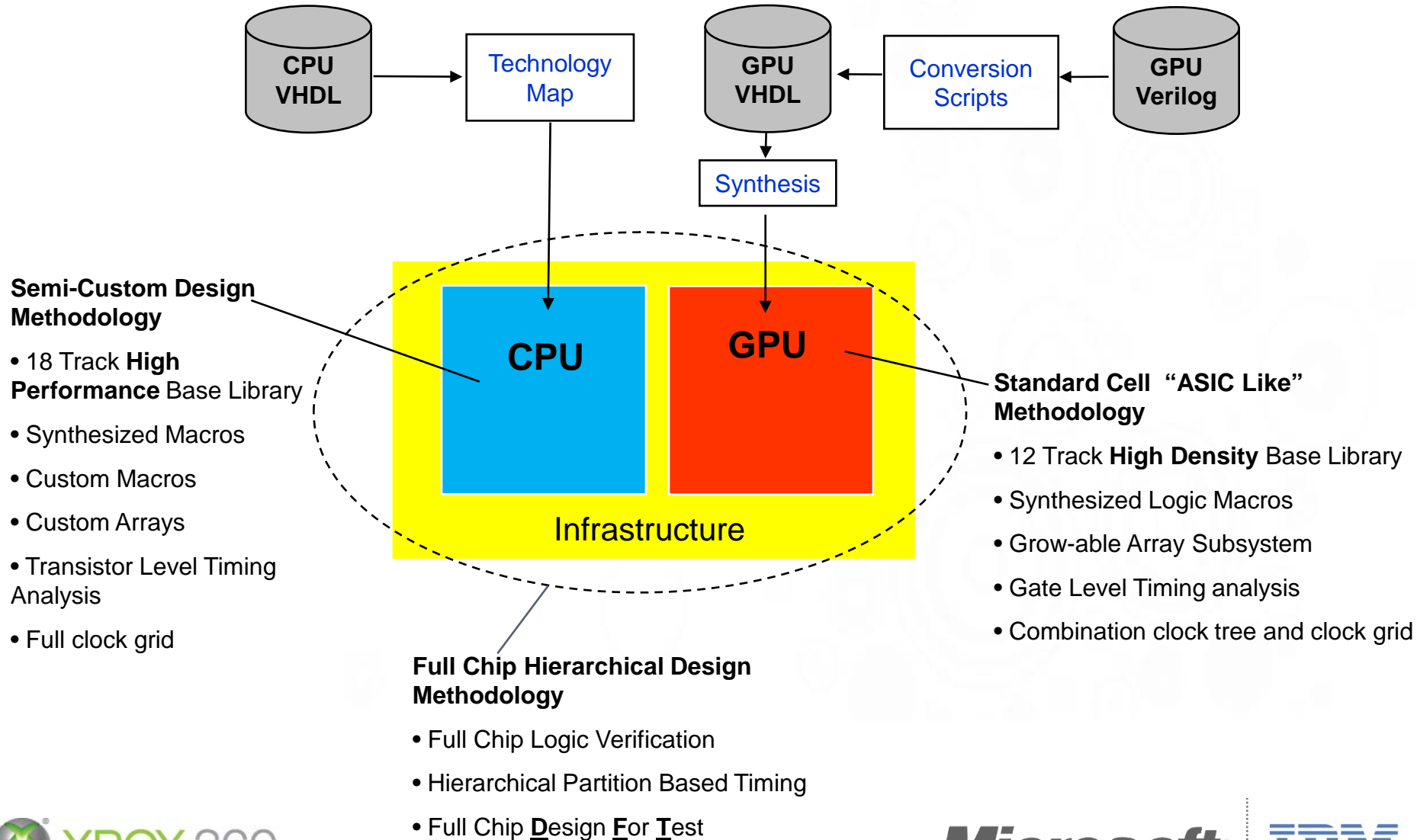
Power Delivery

- Adaptive Power Supply (APS)
- 8 Power Domains

Manufactured by multiple foundries

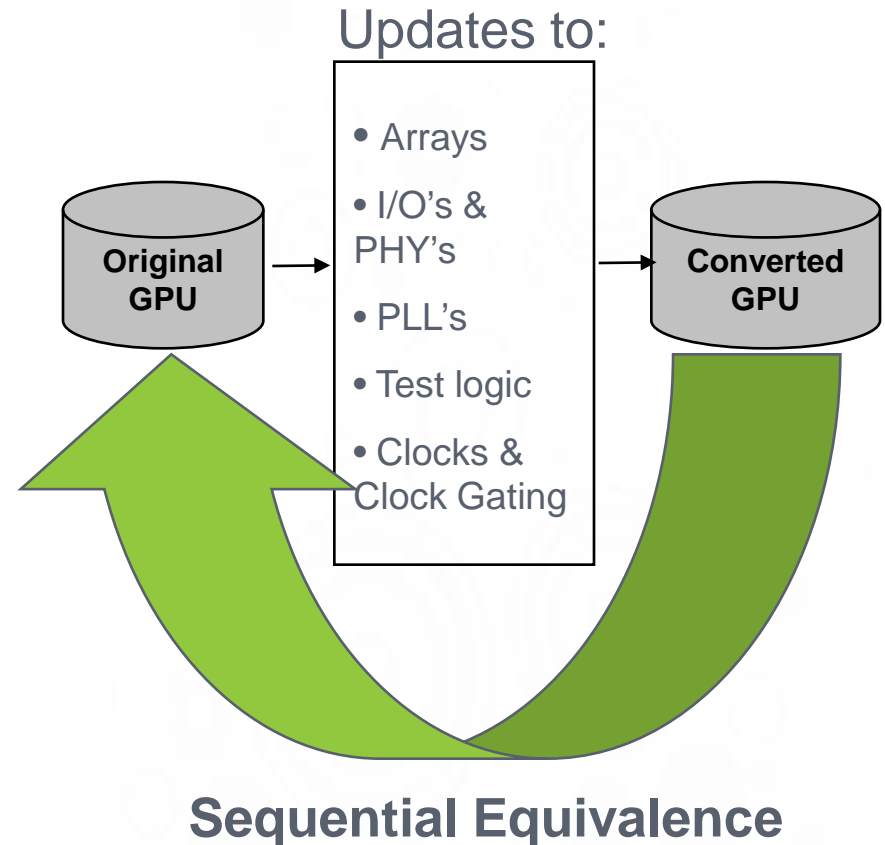


Implementation Challenge: High Performance + Density



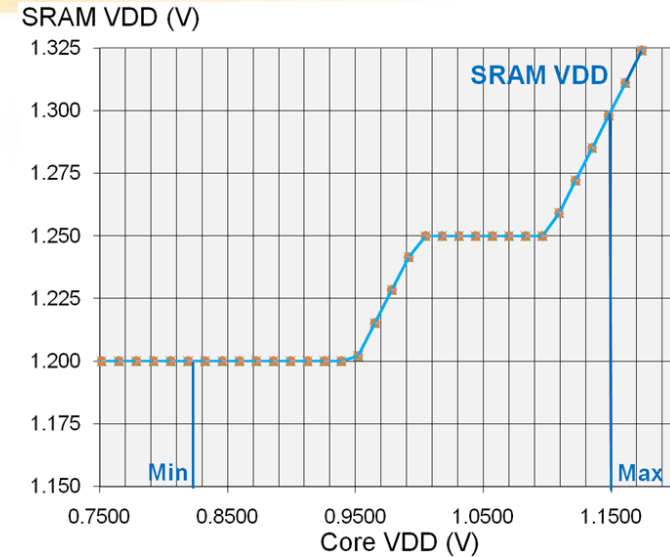
Implementation Challenge: Backward Compatibility

- **Challenge: The new hardware must be 'transparent' to the user**
 - Backward Compatibility is a combination of both performance and function
 - Existing verification environments only validate function
 - Problem compounded by new chip boundaries and technology change
- **Solution: Sequential equivalence used to validate design migration**
 - Compare corresponding sequential path outputs from two different design representations to ensure their function is the same
 - Provides both performance and functional validation for units that didn't change
 - Leveraged IBM developed tool for functional equivalence
- **Solution: Pattern based verification used to focus on any areas of change**
 - Ran existing pattern based test cases to validate functions
 - Wrote new test cases for any areas of change, including the new FSB logic

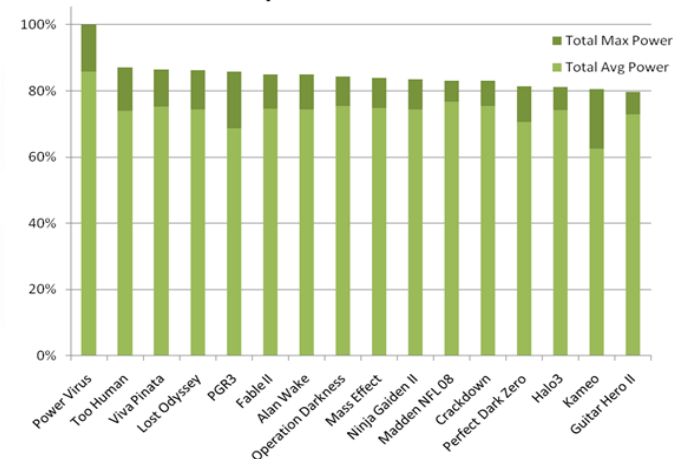


Power Optimization

- Power Optimization Key Design Requirement
- Adaptive Power Supply
 - Part specific supply voltage for Core VDD
 - Separate SRAM supply tracking Core VDD
 - Power saving of 31%
- In System Voltage Regulator Calibration
 - Regulator loadline and tolerance calibrated
 - Ring Oscillator based on-die voltage measurement
 - Power saving of 12%
- Total Power Saving 43%
- Max Power Application – Power Virus
 - Combine CPU + GPU Max Usage
 - Power virus >10% more aggressive than games

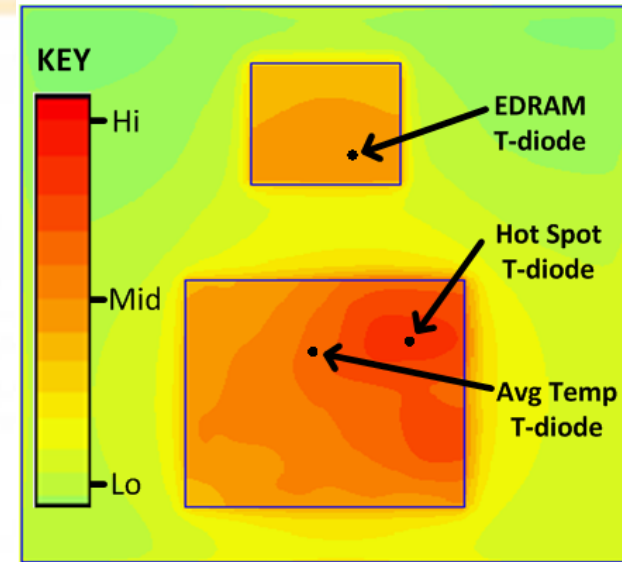


Example Game Power Consumption Compared to Power Virus



Thermal Management

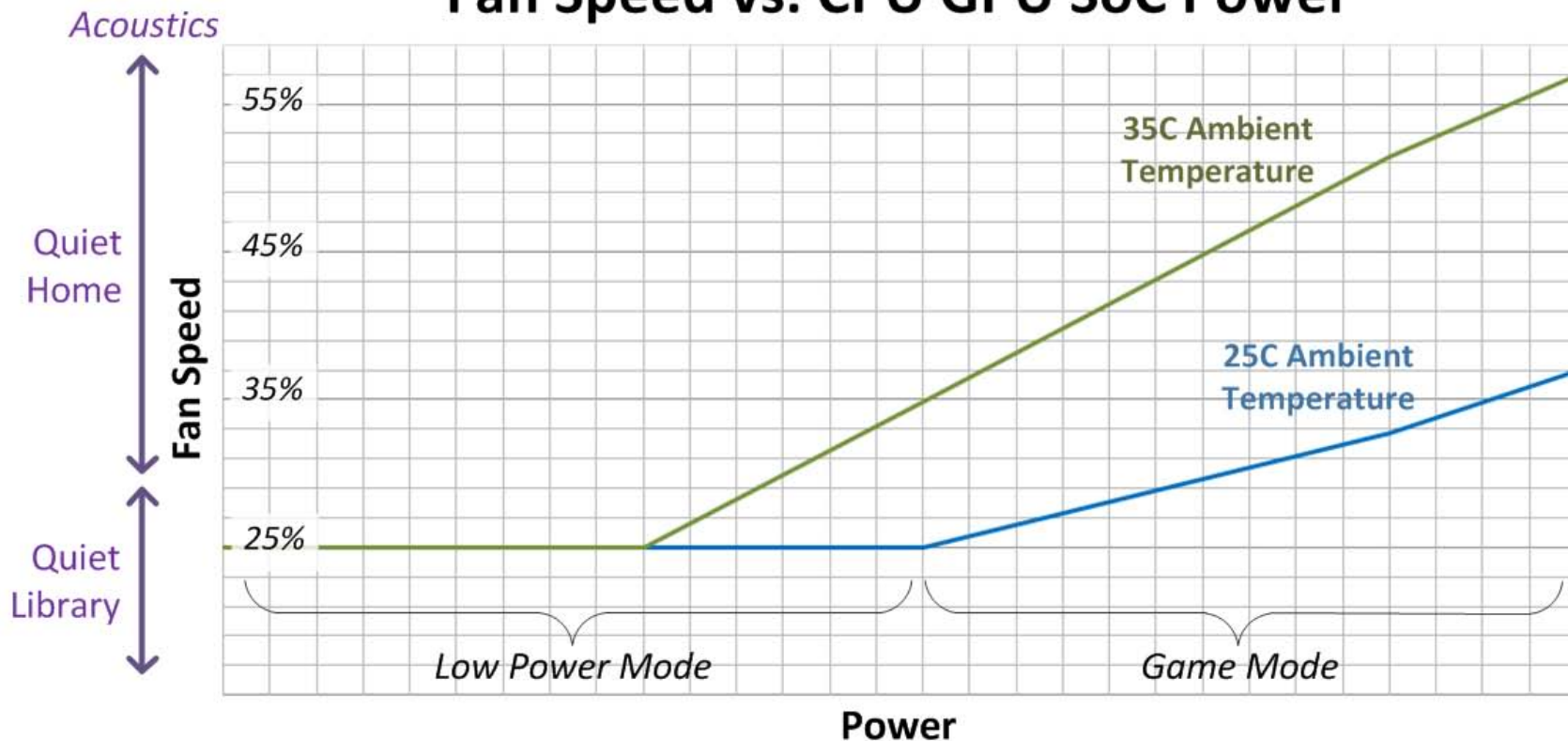
- Requirement: Max hot spot & Max average temperature
 - Must be met regardless of workload
- Power and Thermal Maps created for extreme use cases
 - Combinations of Max/Min CPU and GPU power
- Thermal diode placement dictated by use cases
 - Hot Spot Diode: Between CPU core0 and 1
 - Average Temperature Diode: By GPU shaders
 - Separate Diode for EDRAM
- Thermal set points to ensure ample margin to requirements
 - Closed loop operation based on all T-Diode measurements
 - Goal to keep fan speed low.
 - Set points reduced in low power mode to reduce thermal overshoot when switching to full power mode
- Result: Thermal requirements met



Example Thermal Map

Results from Power and Thermal Optimizations

Fan Speed vs. CPU GPU SoC Power



Console Design Using CPU GPU SoC

○ Power Reduction

- Smaller Power Supply Unit

○ Simplified Motherboard Layout

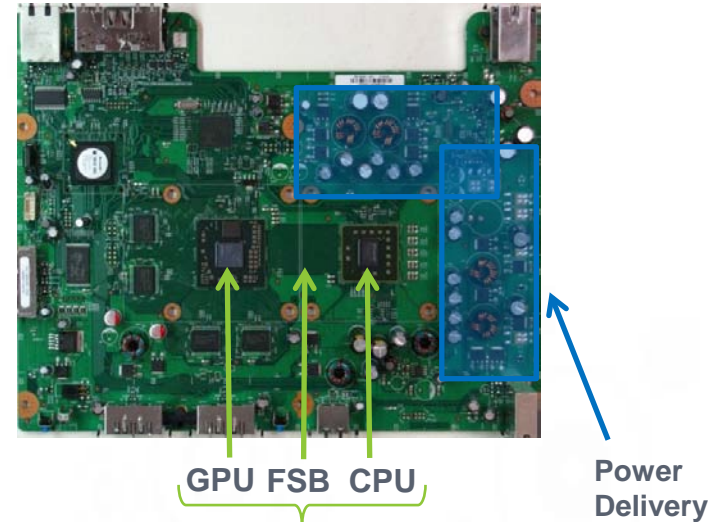
- Single Chip for CPU GPU
- Power Delivery
- Efficient decoupling cap placement

○ Thermal Flexibility

- Single Heatsink
- Single Fan

○ Console Size Reduction

Existing Xbox 360 Motherboard



Motherboard with CPU GPU SoC

Console Design Using CPU GPU SoC

○ Power Reduction

- Smaller Power Supply Unit

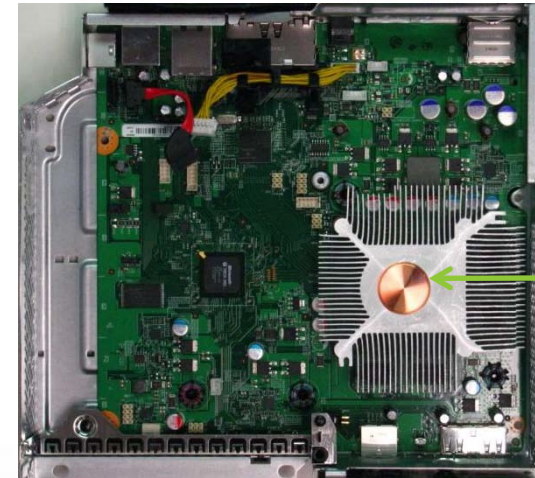
○ Simplified Motherboard Layout

- Single Chip for CPU GPU
- Power Delivery
- Efficient decoupling cap placement

○ Thermal Flexibility

- Single Heatsink
- Single Fan

○ Console Size Reduction



Heatsink

Motherboard + Heatsink

Console Design Using CPU GPU SoC

○ Power Reduction

- Smaller Power Supply Unit

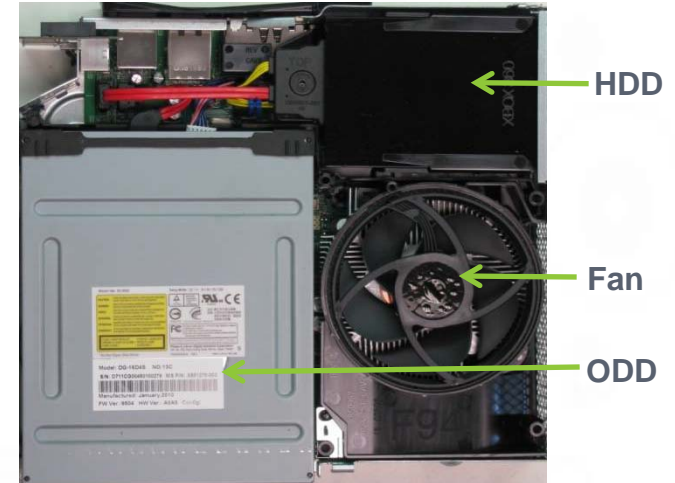
○ Simplified Motherboard Layout

- Single Chip for CPU GPU
- Power Delivery
- Efficient decoupling cap placement

○ Thermal Flexibility

- Single Heatsink
- Single Fan

○ Console Size Reduction



Motherboard, Fan, Optical Disk Drive

Console Design Using CPU GPU SoC

○ Power Reduction

- Smaller Power Supply Unit

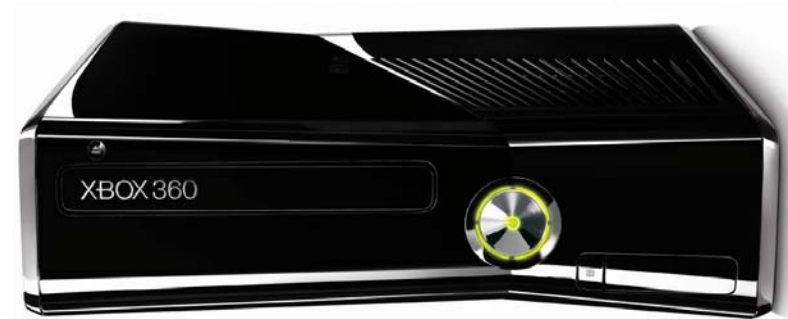
○ Simplified Motherboard Layout

- Single Chip for CPU GPU
- Power Delivery
- Efficient decoupling cap placement

○ Thermal Flexibility

- Single Heatsink
- Single Fan

○ Console Size Reduction



New Xbox 360 250GB Console

Conclusion

- First High Performance Integrated CPU GPU SoC
 - 372M Transistors
 - IBM 45nm SOI Technology
- Enabled Whisper Quiet Console
 - Optimized Power and Thermal Design
- Significant benefits achieved from close collaboration of system and chip design teams



Appendix

Contributing Authors

Dan Kuper, Greg Williams, John Sell, Mike Love, Walker Robb, Ram Kadiyala, Eiko Junus, Jim Barnhart, Kent Haselhorst, Mike Gruver, Bill Hovis, Paul Espeset, Julia Purtell, Michael Lau, Andrew Roedel, Pete Atkinson, Aaron Buerman, Greg Luurtsema, Paul Paternoster

©2010 Microsoft Corporation, IBM Corporation

Microsoft, Xbox 360, Xbox, XNA, Visual C++, Windows, Win32, Direct3D, and the Xbox 360 logo and Visual Studio logo are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

IBM, the IBM logo, and PowerPC are trademarks of International Business Machines Corp., registered in many jurisdictions worldwide.

IEEE is a registered trademark in the United States, owned by the Institute of Electrical and Electronics Engineers.

OpenMP is a trademark of the OpenMP Architecture Review Board.

The names of actual companies and products mentioned herein may be the trademarks of their respective owners.

